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THE EFFECTIVENESS OF ONLINE AND BLENDED LEARNING FROM SCHOOLS: A SCOPING REVIEW

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Executive Summary

This scoping review examines online and blended learning **from** schools (rather than **in** schools). It is particularly relevant at a time when schools have been forced by the covid-19 pandemic to implement some of these measures as pupils have been unable to attend school. In addition, the review investigates Educational Games, Computer Supported Cooperative Learning (CSCL) and Computer Assisted Instruction (CAI), which all have the potential to be used outside school. Web-based learning **in** school was included in CAI.

Eight different research databases were searched. Studies not relating to schools, studies dating before 2000 and duplicates were excluded. Remaining were 1540 studies from all over the world: Online 160 studies (10%), Blended 256 (16%), Games 530 (32%), CSCL 159 (10%) and CAI 520 (32%). There was a very large number of reviews and meta-analyses – 225. Of the 1540 studies, 946 studies (61%) found digital technology better than traditional instruction, while 115 (7%) found it the same. Only 2% (29) found digital technology worse than traditional instruction, although publication bias has to be considered.

CAI performed the best (although a very miscellaneous category), Blended Learning and Games were next equal, with Online and CSCL joint bottom (with fewer papers than the other categories). Overall, 72% of studies gave positive outcomes, with 28% being unclear. In terms of school sectors, Primary performed best; next came Secondary. Early Years and Kindergarten was very similar to Secondary, a very interesting outcome for this group, who might not have been expected to be highly responsive to digital technology. Blended Learning seems more frequent at Secondary than Primary, especially in Science and Maths, although Reading disappears at Secondary level, but a wide range of subjects are studied. Health subjects do particularly well. Online seems to focus more on Maths at Primary level and more on Science at Secondary level, although reading is present at both levels. English as a Foreign Language is also widely pursued through Online and Blended Learning.

Girls did better than boys at digital learning, although often girls and boys were equal. Low ability children were found in several studies to respond to digital technology more positively than “average” children (as they would normally be perceived by the teacher). Generally, Disadvantaged children were mentioned in the context of investigating whether digital technology worked with such children, which it usually did, once it was made reliably available. There were a number of positive studies of digital technology for children with very various special needs: Learning Difficulties, Autistic Spectrum Disorder (ASD), Attention Deficit and Hyperactivity Disorder (ADHD), Deaf and Hard of Hearing, Emotional and Behavioural Disorder (EBD), Downs Syndrome, Visual Impairment and Dyslexia/Specific Learning Difficulties. Generally, studies of Ethnic Minorities reported improvement. Twelve studies found that innovations in Rural schools were effective. Countries Not Speaking English as a first language numbered 59 (357 papers) - it seems very likely that local cultural features need taking into account when implementing digital technology.

Improvement in Socio-Emotional Functioning from engagement with digital technology was reported by 247 studies (16%) (although this was mostly improvement in self-efficacy), while only 18 (1%) reported a deterioration. A large number of studies were noted as having implications for the Design of interventions or for the Digital Pedagogy which they entailed –

410 (27%). We broke them down by intervention and readers will find these details in the Appendix. Implications for practice, policy and future research were discussed, particularly how schools can capitalise on their ventures into online and (particularly) blended learning as they move forward.

For clarity, we now give the Conclusions in a bulleted list:

1. Do online and blended learning from schools have positive/negative/similar effects compared to traditional classroom teaching or digital learning in school? The answer is Positive for both online and blended learning.
2. Do educational games and computer-supported collaborative learning have positive/negative/similar effects compared to traditional classroom teaching or digital learning in school? The answer is Positive for both, although the evidence for Games is more persuasive than the evidence for CSCL.
3. Are the effects different between primary/elementary schools, middle schools and secondary/high schools? There are similar Positive effects in primary and secondary schools, although with less focus on reading in secondary. Science and Maths are the most popular subjects, but many other subjects are learned in this way. There is less research on middle schools. In addition, web-based learning which was carried out in schools was categorised under Computer Assisted Instruction (CAI), which was also found to be effective, and clearly has the potential to be used outside of school.
4. Are the effects different in different subjects? A wide range of subjects shows positive results, not only Reading, Maths and Science/STEM, but also English, Writing, English as Foreign Language, Critical Thinking, Humanities, Art and Music, and Health.
5. Are the effects different by gender? They are, and girls generally do better than boys. So, the idea that boys are more competent at information technology is an urban myth.
6. Are the effects different for different sub-groups of students? Positive effects are more marked for students of low ability. Disadvantaged and rural students show positive results where access to digital technology is arranged. A wide range of students with special educational needs or disabilities and those from ethnic minorities show positive results. Students in Non-English-Speaking Educational Contexts show positive results even though the 59 countries they live in are likely to have cultural issues particular to digital learning.
7. Are the effects on socio-emotional functioning and psychological wellbeing positive/negative/similar compared to being in school full-time? The effects on Socio-Emotional Functioning are largely positive although many studies focused only on self-efficacy. Psychological Wellbeing had too few studies to generate any conclusion.
8. What is the evidence for design principles or underlying digital pedagogies in any of these studies? There is a great deal of evidence on these areas which is summarised and given in more detail in the Appendix.
9. What teaching points for effective online/blended learning can be drawn from evidence-based studies? This research question will be answered after we have read the full papers.

The report can be downloaded from:
https://www.dundee.ac.uk/media/dundeewebsite/eswce/documents/research/scoping-review-2.docx

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The Effectiveness of Online and Blended Learning from Schools: A Scoping Review

This literature review starts with an Introduction which outlines the urgent need for the study, in view of the heightened demand created by the corona-virus pandemic. It notes that many of the studies on online and blended learning have been conducted in higher education. However, the present review of online and blended learning **from schools** since 2000 encompasses 1540 studies, so clearly there is a good deal of research on this also. Definitions of blended and online learning (and synonyms) are offered. Previous literature relevant to this review is briefly surveyed, then Research Questions are given. Turning to Method, keywords, databases and inclusion/exclusion criteria are outlined. The coding framework is explicated and inter-rater reliability outlined. Results are then given, albeit in summary form. The paper ends with a Discussion (which gives the opportunity to discuss limitations and speculate beyond the research findings) and a Conclusion (which gives the answers to the Research Questions).

Introduction

Aims

During the corona-virus pandemic, many schools turned to online and blended learning in various forms to provide education for children who were not allowed in school. Papers have begun to appear on managing online and blended learning in a pandemic (e.g., Doucet, Netolicky, Timmers, & Tuscano, 2020), but these are typically just giving advice and listing resources with no evidential basis. We do not know how well schools have been delivering online learning, and probably there was great variation between schools (and possibly between teachers). Undoubtedly the transition from classroom work to online work has been extremely demanding for many teachers. Further, disadvantaged students may be less likely to have computers and wifi connections at home (although they may be more able to access material delivered to mobile phones), and so the gap between advantaged and disadvantaged students seems likely to increase.

The aim of this review is to explore the research literature on the effects of online or blended learning from schools to see whether it is better, worse or the same as traditional face-to-face classroom learning, in order that teachers might be better informed. If online or blended learning turns out to be as good as or similar to classroom learning, teachers may wish to extend their involvement in it even after children are able to return to school. Of course, there may be local lockdowns which require only a limited number of children to be in school, and blended learning would be ideal in that instance. The developed skills in delivering online learning should not be lost by simple reversion to “what we always did before”. Thus, this project also aims to extract evidence-based teaching principles which teachers can actually put into practice. Of course, online learning may be good for some sub-groups of students but not others, and this needs to be made clear also.

Research studies are typically moderately well organised, so they may not be typical of what has recently happened in schools, i.e., a scramble at short notice to deliver any kind of support to pupils via online learning. Consequently, recently implementation might have been of uncertain quality in some schools, which might make recent practice less related to the

research outcomes than would otherwise be the case. However, research studies are also affected by publication bias, in that authors are more likely to submit for publication papers reporting positive results, and journal editors are more likely to publish them. So, they may give a somewhat unrealistically positive picture of the effectiveness of intervention methods.

Given the need to get reliable information into the hands of teachers at the earliest possible date, once we had coded all the abstracts of the papers, we decided to produce a Scoping Review based only on the abstracts and make that available to teachers, which would give a rough approximation of what the final study was likely to offer. We intended to use feedback on the Scoping Review to inform the development of the final Systematic Analysis report based on reading the full papers.

Definitions

Online Learning is a style of education in which students learn complete programmes only via electronic and online media, so that they can completely control the time, pace, and place of their learning (Oxford English Dictionary). In other words, all the learning happens out of school. However, many studies report what they call online learning when in fact they have the pupils in school using the school wifi to access some form of web-based programme under the supervision of the teacher. This is not what we consider to be online learning, and such projects have been categorised as Computer Assisted Instruction (CAI).

Blended Learning is a style of education in which students learn via electronic and online media as well as traditional face-to-face teaching in the classroom, so that they can, in part, control the time, pace, and place of their learning (Oxford English Dictionary). In other words, part of the learning happens out of schools and part of it happens in schools. Typically, information-giving happens out of school and interactive elements such as teacher and peer discussion happen in school.

In both online and blended learning, online interactive sessions between teacher and student or between student and peers can be hosted through video conferencing, web chat, message boards or other means. In this review, online or blended learning may have taken place for the entire programme of learning, or it may only have taken place for the relatively brief project which is reported.

In this report we not only consider online and blended learning, but also computerised educational games and computer-supported collaborative learning, since these may mainly currently be used in school but clearly have the potential to be used in locations outside of school.

Computerised educational games are games that are designed to help people learn about certain subjects, expand concepts, reinforce development, understand a historical event or culture, or assist them in learning a skill as they play. They can be “serious” games designed especially for their educational value, or commercial games which nonetheless have educational value (and are often better produced). Games involve interactive play that teaches goals, rules, structure, adaptation and problem solving, all often represented as a story. They provide feedback and enable learning by giving enjoyment, passionate

involvement, structure, motivation, ego gratification, adrenaline, creativity, social interaction and emotion. A “serious game” is a game designed to facilitate learning as well as entertainment (although adults would be well advised not to refer to them as “serious” games in front of the pupils). Games may be for single players, for two or several players, or be part of a massively arranged system for multiple cooperative teams or adversaries, as in Massive Multiplayer Online Games (MMOGs) (Wikipedia).

Computer Supported Collaborative Learning (CSCL) concerns how collaborative learning supported by technology can enhance peer interaction and work in groups, and how collaboration and technology facilitate sharing and distributing of knowledge and expertise among community members (Lipponen, 2002). The participants use the Internet and Internet-enabled software tools to support social and collaborative learning at a distance from one another and from their instructor.

We did not include Computer Assisted Instruction (CAI) or any associated search terms in our literature search. However, as noted above, we found that many studies which purported to be of online or blended learning actually turned out to be school-based studies, where pupils had interacted with digital materials or used web-based materials while under the direct supervision of the teacher. Hence, we categorised these as CAI, a category which grew very large. Clearly, schools are using many forms of technology in schools which could be exported out of school, but to a considerable extent this is not yet occurring. Consequently, a definition of CAI is given: CAI is an interactive instructional technique using a combination of text, graphics, sound and video whereby a computer is used to present a programme of instructional material, have the student interact with it, and monitor the learning that takes place. CAI programmes can be simply drill and practice, or they can be much more complex, e.g., involving simulations (WikiEducator).

Previous Literature

Many useful guides to blended learning appeared before the pandemic (e.g. Cleveland-Innes, & Wilton, 2017). Since the pandemic started, the Education Endowment Foundation (EEF) (2020) has produced a rapid research review of online and blended learning from schools (https://educationendowmentfoundation.org.uk/public/files/Remote_Learning_Rapid_Evidence_Assessment.pdf). Although very valuable, this study only reviewed reviews and meta-analyses (and then not all of them), whereas we intend to review individual studies. Additionally, this study was wider than our focus. Further, the summary teaching points emerging from it were rather difficult for teachers to operationalise. The EEF also focused heavily on disadvantaged children, whereas we looked at other sub-groups. However, we used the reviews in the EEF and also all the single studies cited in those reviews since 2000 in our own review. This report also categorises these studies in the same way as the EEF report, i.e. as Online, Blended, Games, CSCL, or CAI.

In the US, Studies of Distance Learning (https://ies.ed.gov/ncee/wwc/distancelearningstudy) gives a list of studies relevant to online and blended learning across all sectors of education which have partially stemmed from searching ERIC with regard to blended and online learning and partially from crowd-sourced suggestions for relevant studies. We extracted the studies concerned with schools and added them to our study.

Beyond this, Evidence for Learning Australia (https://www.evidenceforlearning.org.au) have been analysing single studies from the EEF Rapid Evidence Assessment. We also do this, but add findings from several other databases. The Scottish Government has produced two papers on Blended Learning (https://education.gov.scot/improvement/learning-resources/education-recovery-group-blended-learning), but these add little to the EEF paper.

Research Questions

RQ1: Do online or blended learning from schools have positive/negative/similar effects compared to traditional classroom teaching or digital learning in school?
RQ2: Do educational games and computer-supported collaborative learning have positive/negative/similar effects compared to traditional classroom teaching or digital learning in school?
RQ3: Are the effects different between primary/elementary schools, middle schools and secondary/high schools?
RQ4: Are the effects different in different subjects?
RQ5: Are the effects different by gender?
RQ6: Are the effects different for different sub-groups of students, e.g. disadvantaged, "high" and "low" ability, those with special educational needs or disabilities, ethnic minorities, rural students, second language learners, the hospitalised and sick at home, gifted, and students in non-English-speaking educational contexts?
RQ7: Are the effects on socio-emotional functioning and psychological wellbeing positive/negative/similar compared to being in school full-time?
RQ8: What is the evidence for design principles or underlying digital pedagogies in any of these studies?
RQ9: What teaching points for effective online/blended learning can be drawn from evidence-based studies?

Method

Keywords

We used the following keywords in our search:

- school (including primary and secondary, middle, elementary and high) AND
- blended learning OR online learning OR e-learning OR elearning OR virtual learning OR distance learning OR remote learning OR digital teaching OR flipped learning OR flipped classroom OR computer supported collaborative learning OR computer supported cooperative work OR online cooperative work OR online collaborative learning OR educational games online OR educational video game OR serious games

We initially added a third term (AND effect OR impact OR outcome), but found that this seriously restricted the number of hits in different databases. These words did not appear frequently in titles, abstracts or keywords.

The whole search term was thus:
school AND "online learning" OR e-learning OR elearning OR "virtual learning" OR "distance learning" OR "remote learning" OR "digital teaching" OR "blended learning" OR "flipped learning" OR "flipped classroom" OR "Computer Supported Collaborative Learning" OR "Computer Supported Cooperative Work" OR "Online Cooperative Work" OR "Online Collaborative Learning" OR "Educational Games Online" OR "Educational Video Games" OR "Serious Games".

When we came to Google Scholar, we found that inserting the whole search term was not efficient – it appeared to confuse its algorithms. By experimentation we found that inserting the type of school first (primary/elementary/middle/secondary/high) and then the type of intervention separately ("online learning" OR e-learning OR elearning OR "virtual learning" OR "distance learning" OR "remote learning" OR "digital teaching"/ "blended learning" OR "flipped learning" OR "flipped classroom"/ "Computer Supported Collaborative Learning" OR "Computer Supported Cooperative Work" OR "Online Cooperative Work" OR "Online Collaborative Learning"/"Educational Games Online" OR "Educational Video Games" OR "Serious Games") yielded a far larger and more focused set of hits.

Databases

We searched the following research databases:

- ERIC
- JSTOR
- Scopus
- Web of Knowledge
- Google Scholar
- EEF Rapid Evidence Assessment: Reviews
- EEF Rapid Evidence Assessment Single Studies
- Studies of Distance Learning

All papers dated before 2000 were removed. Then, all papers which appeared from their title or abstract to be about learning other than in school education were removed. After that all whole books and chapters and items which did not have an abstract were removed. After that all items which we could not find an abstract for were removed. See the Prisma chart (Table 1 below) for an indication of the quantity of papers from different databases – there were very different numbers. Also, the number of duplications were small, indicated each database was effectively accessing a largely different range of items. While the EEF Rapid Review listed a considerable number of reviews, systematic analyses and meta-analyses of online and blended learning, games and CSCL, we found many more. However, many of these did not give a clear indication of overall outcome in the abstract.

The Coding Framework

Abstracts were then coded according to the research questions on which they provided data. Papers which were reviews or meta-analyses were coded as such. Papers were coded according to whether they appeared to be in the Online, Blended, Games, CSCL or CAI categories or unclear (irrespective of what they claimed to be). Studies were then coded according to what sector of education they related to: Early Years or Kindergarten, Primary or Elementary, Middle, Secondary or high, Primary and Secondary together, and unclear. Early Years or Kindergarten was included as a category as many readers would not expect online or blended learning to be applicable to such young children.

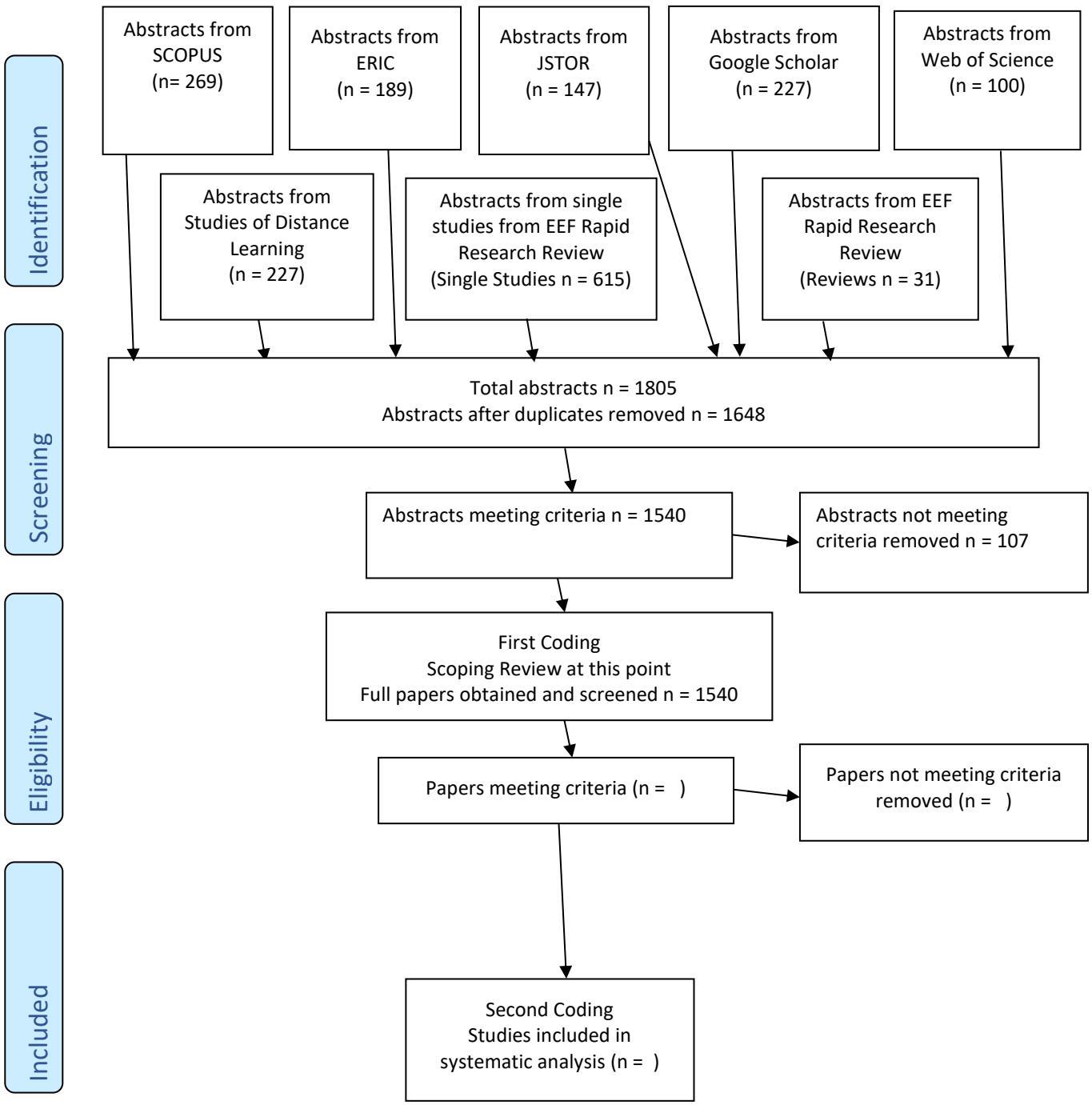
Studies were then coded according to subject area: Reading, English, Writing, Math, Science, STEM (Science, Technology, Engineering and Mathematics), Thinking / English as a Foreign Language (EFL), Humanities (including history, geography, social studies, economics), Health (including physical education, nutrition, exercise, aggressive behaviour), and ArtsMusic (including composing, sculpting).

Studies were coded according to gender if that was mentioned in the abstract, in relation to whether Females were better, Males were better, or Females and Males were equal. Studies were then coded according to sub-group: Socio-economically disadvantaged, of High or Low ability (almost all of low ability), whether participants had any Special Educational Needs or Disability, were of any Ethnic Minority within one country, were mainly in a Rural setting (since online and blended learning are particularly relevant for those far from a school), were Second Language Learners (although most of the findings here were related to those studying English as a Foreign Language), Hospitalised or Sick at Home children, Gifted children, and those in a Non-English-Speaking Educational Context (since we wished to see how many different countries apart from English-speaking countries participants came from in order to consider whether their host educational culture had any differences from the West).

Then Outcomes were considered: was the intervention better, worse or the same compared to whatever it was being compared to? In many cases the comparison was to traditional teacher-led education, but sometimes it was in comparison to another computer-led intervention.

Then Socio-Emotional Functioning was considered – was there evidence that the implementation of online or blended learning has improved social functioning, worsened it, or

PRISMA 2009 Flow Diagram



had it stayed the same? Obviously, online learning in particular removes the face-to-face social interactions which pupils enjoy in school, so this category was apposite. Similarly, Psychological Well-being was considered, although relatively few studies mentioned this.

Finally, coding considered whether the paper had implications for intervention design or described any underlying digital pedagogies, whether this was claimed in the abstract or not. It was anticipated that at the stage of Scoping Review it might be possible to assemble these design points for teacher information, but that a full discussion of teaching points would have to wait until the final systematic analysis.

Inter-Rater Reliability

Coding was undertaken by two senior researchers who were very familiar with this research area. The central 100 studies were coded by both raters and the results compared. It was agreed that only topics mentioned in the title or abstract would be coded. It was also agreed that the raters would avoid creating new groups. Inter-rater reliability was 81%. While this was at best modest, we noted that we were coding on a large number of moderator variables and that we were doing so only on the abstract rather than the full paper, so we considered 81% to be good enough bearing in mind the complexity of what we were attempting.

The subsequent discussion comparing IRR results for each coder led to some interesting findings. Many studies which appeared to be of Online and Blended Learning did not in fact conform to our definition of these – involving children studying in part or wholly at home or otherwise outside of school, using the Internet or CDs or paper materials. These studies might well have had pupils using web-based learning or digital packages, but these were only studied in school (using the school's own wifi), rather than in any way at home. It was agreed to code such studies CAI rather than O or Bl. However, studies of Games and CSCL were less readily divided in this way, and consequently all studies of Games and CSCL might be of these used in school (with potential for use at home) or actually at home. Additionally, there was discussion of the concept of Non-English-Speaking Educational Context (NESEC), indicating countries where English was not the native language and where the educational context might be very different from what would be expected in the UK. Ethnic Minority (EM) would be used for an ethnic minority within a country, rather than between countries.

After this discussion the IRRs were cross-referred and any disputed cases were resolved by discussion. We anticipate that this discussion would lead to an IRR percentage higher than the 81% found in this instance, but we do not propose to conduct another IRR until the second stage of this research, after we have read all the papers.

We initially deliberately excluded Computer Aided Instruction (CAI) from our search terms as such methods are mostly only found in the classroom. However, some CAI methods have **potential** for use in blended learning, and where our search nonetheless discovered such items, we have included them in our results here. Likewise, some of the Games and CSCL we reported were used in a classroom environment, but clearly had potential to be used in a blended learning environment. Only items which were clearly about online learning were coded under online learning, and only items clearly about blended learning coded under blended learning.

One option we did not pursue was to code online/blended learning as synchronous or asynchronous. It has been argued that web-based learning in school is more likely to be synchronous, whereas online/blended learning outside of school is more likely to be asynchronous, offering a higher level of flexibility concerning mode, place, pace and path. In the event, few of the abstracts mentioned this variable, and most research finds no difference, and so it was excluded.

Quality of Studies

We considered rating Quality of Evidence from 1 to 4 using the GRADE framework of Guyatt, Oxman, Akl, Kunz, Vist, Brozek, et al. (2011), but the studies were so various and only the abstracts were inspected in the first stage, so this was eventually considered too subjective and unreliable for weighting purposes.

Results

As noted earlier, 1540 studies were included in this review. Dividing these into area of operation, we found: Online 160 studies (10%), Blended 256 (16%), Games 530 (32%), CSCL 159 (10%) and CAI 520 (32%) (some studies encompassed more than one area of operation). Other studies were unclear in the abstract about what they were investigating. Clearly, Games and CAI were categories containing many studies, while Online and CSCL contained least, with Blended Learning somewhere in the middle.

We also noted the very large number of reviews and meta-analyses – 225 in total, divided into Online 28, Blended 40, Games 78, CSCL 26 and CAI 42. There were an additional 11 reviews where it was impossible to tell from the abstract what intervention they were reviewing. Unfortunately for our purpose, many of these reviews covered primary, secondary and higher education together. Where this was the case, the majority of the studies usually came from higher education. It was rare for there to be any discrimination in the abstract about what sector of education the studies came from. The number of reviews per area of operation was in line with the number of studies, except CAI was under-represented. Consequently, the number of individual studies excluding reviews were: Online 132, Blended 216, Games 452, CSCL 133 and CAI 478, with a total of 1411.

Considering the indications regarding outcomes, 946 studies (61%) found digital technology better than traditional instruction, while 115 (7%) found it the same. In a further 376 studies (24%) the outcome was unclear. Only 2% (29) found digital technology worse than traditional instruction, while a further 93 studies (6%) were not coded as anything. This is clearly a major finding, indicating that digital technology is almost always superior to traditional instruction, although of course publication bias has to be taken into account.

Analysis by Intervention x Sector x Subject x Outcome

It was clearly of interest to investigate the extent to which these overall positive findings remained when different interventions were analysed: Online, Blended, Games, CSCL and CAI. It was also of interest to investigate the extent to which these overall positive findings remained when different sectors of education were analysed: Early Years Kindergarten, Primary, Middle, Secondary and Primary + High schools. We created a matrix which explored the interactions between these factors. Within this matrix (in each cell) we also investigated subjects: Reading, Maths, Science, STEM, Thinking, EFL, Humanities, English, Health, Art Music, and Writing. Within each sub-cell, we also investigated Outcomes: Better than traditional instruction, Same, Worse or Unclear. The Unclear category itself split into various sub-categories: Unclear because Subject unclear, Unclear because Sector unclear and Unclear because Intervention unclear. The resulting matrix was extremely complex and here we merely try to summarise it. Table 1 gives summary data for Interventions, while Table 2 gives summary data for School Sectors.

Table 1
Summary Data for Interventions

Intervention	Better	Same	Worse	Total Unclear (%)+	Total Better/ Same (%)+
Online	50	6	2	55 (39%)	78 (55%)
Blended	105	10	0	65 (30%)	150 (70%)
CSCL	45	2	1	57 (46%)	65 (53%)
Games	246	29	5	142 (29%)	348 (70%)
CAI	287	39	8	96 (20%)	379 (78%)
Unclear	31	9	0	7 (15%)	40 (85%)
Overall Total				422 (28%)	1060 (72%)

+ Percentages include Worse outcomes

Table 2
Summary Data for School Sectors

School Sector	Better	Same	Worse	Total Unclear (%)+	Total Better/ Same (%)+
Early Years/ Kindergarten	25	2	1	10 (25%)	28 (70%)
Primary/ Elementary	363	32	6	67 (13%)	437 (85%)
Middle	48	14	3	50 (38%)	74 (56%)
Secondary/ High	234	31	5	112 (26%)	315 (72%)
Primary + Secondary	63	7	1	75 (40%)	106 (56%)
Unclear	31	9	0	7 (15%)	40 (85%)
Overall Total				321 (24%)	1000 (76%)

+ Percentages include Worse outcomes

Table 1 indicates that in terms of the ratio between Better + Same outcomes and Unclear outcomes, CAI performed the best (78% vs. 20%) (even though it was a very miscellaneous and make-weight category in this analysis, and might have caught more studies of less rigour). Hopefully this issue can be resolved when we read the full papers. Blended Learning and Games were next equal (both about 70% vs. 30%), with Online and CSCL coming joint bottom (about 54% vs. 42%). However, many studies coded as CSCL did not set out to measure learning improvement, but instead some variant of SEF such as communication, social interaction or self-efficacy. With CAI, Blended Learning and Games we can be sure that the numbers of Better + Same far outweigh the numbers of Unclear, so even if all the Unclear were negative (which is highly unlikely given the very small numbers of Worse in this analysis), Better + Same would still be the largest category. This is less clear with Online and CSCL. Overall, 72% of studies gave positive outcomes, with 28% being unclear.

Table 2 indicates that Primary Elementary performed the best, with 85% in the Better or Same category and only 13% in the Unclear category (although it should be noted that this was very similar to the Overall Unclear category). Next came Secondary High, with 72% in the Better or Same category and 26% in the Unclear category. Early Years and Kindergarten was very similar to this, with 70% in Better/Same and 25% in Unclear, and this is a very interesting outcome for this group, who might not have been expected to be highly responsive to digital technology. As with the previous table, all of these would remain positive even if all the Unclear turned out to be negative, which is highly unlikely. This is less true of Middle schools and the Primary + Secondary combination. It is not clear why Middle schools should not do so well. Regarding the Primary + Secondary combination, it seems more difficult for any digital technology to be able to cover such a wide age range, so perhaps digital technology is better focused on either Primary or Secondary.

Other more nuanced findings are evident from the whole matrix. Games and CAI obviously dominate in terms of number of studies, particularly at Primary level, with Games much more prevalent at Primary than Secondary. Games are also more common in Primary + Secondary studies than CAI. Maths and Science are the most common subject in Games and CAI in Primary, joined by Reading especially in CAI. However, Games are also common in many other subjects in Primary and similarly (although to a lesser extent) in Secondary. However, in Secondary, Maths becomes less common and Science becomes more common in CAI, while Reading disappears from Games.

Blended Learning is of interest as it seems more frequent at Secondary than Primary, although again Reading disappears at Secondary level. Science seems to be the most popular subject. With Maths following shortly behind. Again, a wide range of subjects are studied at both Secondary and Primary. Health subjects seem to do particularly well. Online and CSCL seem to be the weakest interventions among those studied, but this is only relative as they also have substantial research evidence to support them. Online seems to focus more on Maths at Primary level and more on Science at Secondary level, although reading is present at both levels. English as a Foreign Language is also widely pursued through Online Learning (and features in Blended Learning as well). CSCL is somewhat similar, with less emphasis on Reading and Maths at Secondary and more on Science.

Other Moderator Variables

Gender was coded according to whether Females did better, Males did better, Males and Females were equal, some Other aspect of gender, or whether gender was mentioned but Unclear. Females were better in 27 cases and Males better in only 4. Males and Females were equal in 35 cases. Other was 6 cases and Unclear 21. Thus, somewhat contrary to expectations, girls did better than boys at digital learning in many studies, although the majority of studies had girls and boys doing equally well.

Special sub-groups were coded according to whether they were: Disadvantaged, of HiLo Ability (almost all of "low ability"), had Special Educational Needs or Disabilities, were from an Ethnic Minority, were from Rural areas (where remote learning might be more needed), were Second Language Learners (almost all EFL studies), were Hospitalised or Sick at Home children, were Gifted, and whether they came from a Non-English-Speaking Educational Context. Studies coded as Disadvantaged numbered 52 (3%), HiLo 89 (6%), a variety of Disability 115 (7%), Ethnic Minority status 33 (2%), Rural 41 (3%), Second Language Learners 89 (6%), Hospitalised or Sick at Home 8 (.5%), Gifted 10 (.6%) and Non-English Speaking Educational Context 357 (23%).

Regarding Disadvantaged, we expected to encounter some direct discussion of the presumed difficulties for socio-economically disadvantaged children of accessing computer and the Internet at home, but there was very little of this, other than some comment on such children possibly having less support from parents, who would need to work and in the case of blended or online learning would be leaving the child at home unaccompanied, which of course would be illegal in the case of young children. Perhaps deeper analysis of this issue will become evident once we read the full papers. Given the attainment gap between advantaged and disadvantaged students, there was a danger that digital technology would serve only to make that gap wider. Generally, the mention of Disadvantaged was in the context of investigating whether digital technology worked with such children, which it usually did once it was made reliably available. Some schools had made iPads or laptop computers available to Disadvantaged children to take home, with positive results. A few studies had tried using mobile phones rather than computers and the Internet. There was also comment on the loss of educational capability during the summer break for disadvantaged children.

The code HiLo almost exclusively related to "low ability" children (as they would be perceived by the teacher), who were found in several studies to respond to digital technology more positively than average children. This suggests that children operating in the digital space can prove surprisingly competent when given the opportunity (although "weaker" students might be expected to perform more poorly). Again, direct comparisons of low ability and average ability students was rare. An early start with Kindergarten children was found effective. However, there were relatively few direct comparisons of low ability and average ability children.

The Special Educational Need or Disability code revealed use of digital technology in a number of studies of children with very various needs, including: All unspecified SEN 15, Learning Difficulties 23, Autistic Spectrum Disorder 13, Attention Deficit and Hyperactivity Disorder 9, Deaf and Hard of Hearing 5, Emotional and Behavioural Disorder 4, Downs Syndrome 3,

Writing Difficulty 3, Visual Impairment 3, Dyslexia/Specific Learning Difficulties 3, English as a Second Language 2, Mental Health Disorders 2, Mathematical Learning Difficult/Dyscalculia 2, Reading Difficulty 1 and Sensory Processing Disorder 1.

Ethnic Minority Status was often seen in US studies as Afro-American (7 studies) or Hispanic (8 studies). However, East Africans also featured (2 studies) as did Native Americans and Maori (1 study each). Ten studies spoke of all ethnicities without specifying. Generally, studies focusing on Ethnic Minorities reported improvements. More than one study noted that Computer Science was dominated by White and Asian males.

Rural schools were widely seen as problematic, not just because of a lack of resources and Internet connectivity, but also because in some countries school income could be less and the teachers could be less qualified. However, three studies found that innovations were as effective in rural schools as elsewhere. Nine studies focused on digital innovations within rural schools, which were mostly found to work. Another nine studies discussed improving remote rural schools more generally, through schemes like My Buddy School linking a rural and an urban school and the wider use of mobile phones. One study distributed iPads while another distributed the much cheaper Raspberry Pi. A third distributed unspecified tablets with games on them. Online mentors were mentioned.

We hoped the coding for Second Language Learners would help us discover students who were not speaking their native language in class. However, the bulk of this category was taken up by English as a Foreign Language learners.

A few studies focused on children who were Hospitalised or Sick at Home, which was acknowledged to be a very difficult situation. Some of these focused on children with chronic conditions (e.g. leukaemia) who were hospitalised for a long time, but the value of educational engagement was emphasised and these children were supported with digital technology, including Virtual Reality. Other studies considered conditions which did not require long-term hospitalisation, although results were mixed.

The Gifted coding revealed studies concerned with intervention with gifted students in mathematics (2 studies), language, writing, neuroscience and metacognition. Two studies compared gifted and non-gifted students and expressed surprise when the non-gifted did as well as the gifted. This again suggests that “giftedness” is traditionally defined by the school and pupils with digital competencies may achieve unexpected performance in that area. Gifted students found virtual learning little different from traditional learning at school, apart from the social side of life.

Non-English-Speaking Educational Context was coded whenever the title or abstract indicated the study had taken place in a country which did not have English as its first language. This was intended to show that different cultural factors may be operating which could influence the success or otherwise of the digital technology. The following countries were so identified (in order of frequency of studies and then alphabetically): Taiwan 73, Indonesia 35, Turkey 31, China 21, Hong Kong 15, Spain 14, Malaysia 13, India 12, South Korea 11, Iran 10, Netherlands 9, Thailand 9, Greece 6, Singapore 6, Chile 5, Israel 5, Mexico 5, Brazil 4, Cyprus 4, Czech Republic 4, Nigeria 4, Columbia 3, France 3, Italy 3, Philippines 3, Saudi Arabia 3, Sweden 3,

Denmark 2, Ethiopia 2, Finland 2, Germany 2, Japan 2, Kenya 2, Kuwait 2, Norway 2, Oman 2, Poland 2, Sudan 2, Austria 1, Belgium 1, Costa Rica 1, Ecuador 1, Ghana 1, Hungary 1, Iraq 1, Jordan 1, Malawi 1, Morocco 1, Nepal 1, Palestine 1, Peru 1, Portugal 1, Slovakia 1, Slovenia 1, South Africa 1, Sri Lanka 1, Switzerland 1, Ukraine 1, United Arab Emirates 1 (59 countries, 357 papers). Clearly, interest in this area occurs all over the world. It seems very likely that there are cultural features that need taking into account when implementing any digital technology. The size and population of a country (and to an extent its level of economic development) bears no relationship to its productivity in this area.

Improvement in socio-emotional functioning as a result of engagement with digital technology was reported by 247 studies (16%), while only 18 (1%) reported a deterioration. A further very small number (8, .5%) found no difference, while in 120 cases (8%) this was unclear. However, a large number of these 247 positive studies were reporting an improvement in self-efficacy, rather than social functioning per se.

Psychological Well-Being was a rarely coded option, only 13 studies (.8%) noting an improvement in this area. However, only one study (.001%) noted a decline in this area, while only two (.001%) stayed the same. Just two studies were coded as Unclear (.001%). Thus, insofar as these numbers are representative, Psychological Well-Being seems very likely to improve with digital technology.

A large number of studies were coded (even from the abstract) as having implications for the Design of interventions or for the Digital Pedagogy which they entailed – 410 (27%). As these will be of interest to teachers, we have broken them down by intervention. However, a number of studies did not specify which intervention they related to, and some studies had implications for design which were too vague to articulate. Consequently, we had 367 pointers regarding design and pedagogy to consider. There were 117 points concerning Games (32%), 96 concerning CAI (26%), 65 concerning Blended Learning (18%), 49 concerning CSCL (13%) and 40 concerning Online learning (11%). These figures were very similar to the numbers in which these categories occurred, except CAI was substantially lower – perhaps surprising as CAI was such a various category. The Design and Pedagogy points for each intervention category are too extensive to list here, but readers will find these in the Appendix. Readers will find interesting similarities between some pointers in different intervention areas – and possibly some contradictions.

Discussion

Summary

This review included 1540 studies: Online 160 studies (10%), Blended 256 (16%), Games 530 (32%), CSCL 159 (10%) and CAI 520 (32%). Clearly, Games and CAI were categories containing many studies, while Online and CSCL contained least. There was also a very large number of reviews and meta-analyses – 225: Online 28, Blended 40, Games 78, CSCL 26 and CAI 42. However, many covered primary, secondary and higher education together, with most studies from higher education and no discrimination between school sectors.

Of the 1540 studies, 946 studies (61%) found digital technology better than traditional instruction, while 115 (7%) found it the same. Only 2% (29) found digital technology worse than traditional instruction, although publication bias has to be considered.

Concerning the interventions, and specifically the ratio of Better + Same outcomes versus Unclear outcomes, CAI performed the best (78% vs. 20%) (but note our previous caveats). Blended Learning and Games were next equal (both about 70% vs. 30%), with Online and CSCL coming joint bottom (about 54% vs. 42%) (but note our previous caveats). Even if all the Unclear turned out to be negative (which is extremely unlikely given the very small numbers of Worse), all intervention categories would still be positive. Overall, 72% of studies gave positive outcomes, with 28% being unclear.

In terms of school sectors, Primary performed best (85% Better or Same; 13% Unclear). Next came Secondary (72% Better or Same; 26% Unclear). Early Years and Kindergarten was very similar to this (70% in Better or Same; 25% Unclear), and this is a very interesting outcome for this group, who might not have been expected to be highly responsive to digital technology.

Games were much more prevalent at Primary than Secondary. Maths and Science were the most common subject in Games and CAI in Primary, joined by Reading especially in CAI. However, Games were also common in many other subjects in Primary and also (although to a lesser extent) in Secondary.

Blended Learning seems more frequent at Secondary than Primary, especially in Science and Maths, although Reading disappears at Secondary level. Again, a wide range of subjects are studied. Health subjects do particularly well. Online seems to focus more on Maths at Primary level and more on Science at Secondary level, although reading is present at both levels. English as a Foreign Language is also widely pursued through Online and Blended Learning.

Girls did better than boys at digital learning in a substantial number of studies, although the majority of studies had girls equal to boys. This finding was somewhat unexpected given the popular assumption of male superiority with computers.

We expected some discussion of the presumed difficulties for socio-economically disadvantaged children of accessing computer and the Internet at home, but there was very little of this. Given the attainment gap between advantaged and disadvantaged students, there was a danger that digital technology would serve only to make that gap wider.

Generally, Disadvantaged was mentioned in the context of investigating whether digital technology worked with such children, which it usually did, once it was made reliably available.

HiLo almost exclusively related to “low ability” children, who were found in several studies to respond to digital technology more positively than “average” children (as perceived by the school).

There were a number of studies of children with very various special needs, especially Learning Difficulties, Autistic Spectrum Disorder (ASD), Attention Deficit and Hyperactivity Disorder (ADHD), Deaf and Hard of Hearing, Emotional and Behavioural Disorder (EBD), Down Syndrome, Visual Impairment and Dyslexia/Specific Learning Difficulties.

Generally, studies of Ethnic Minorities reported improvement. Several studies noted that Computer Science was dominated by White and Asian males.

Rural schools were widely seen as problematic, partly because of insufficient resources and Internet connectivity, but also because school income could be less and teachers could be less qualified. However, 12 studies found that innovations in rural schools were effective.

Whenever the title or abstract indicated the study had taken place in a country which did not have English as its first language was noted in the case of 59 countries. Clearly, interest in this area occurs all over the world and it seems very likely that local cultural features need taking into account when implementing digital technology.

Improvement in Socio-Emotional Functioning from engagement with digital technology was reported by 247 studies (16%), while only 18 (1%) reported a deterioration, although this was mostly improvement in self-efficacy.

A large number of studies were noted as having implications for the Design of interventions or for the Digital Pedagogy which they entailed – 410 (27%). We broke them down by intervention and, although too extensive to list here, readers will find these in the Appendix.

Limitations

This Scoping Review was only of titles and abstracts rather than full papers, which is clearly a major limitation. The length and quality of abstracts varied greatly – however, a short abstract could include all the information we sought. This limitation will be addressed at a later stage when we read all full papers and proceed to a systematic analysis. The exclusion of books and book chapters without an abstract perhaps led to the omission of some useful material, but given the number of papers included this is perhaps a minor issue.

However, we think that the broad terms of the search and the variety of databases used are positive features of this study. As the PRISMA chart shows, different databases tended to yield very different studies, and so we have a wide range of studies. However, the issue of publication bias must be considered. Authors tend to submit and editors tend to publish papers that report positive results, so the published papers here might not be a representative

sample of all research that was done. However, we have included doctoral theses, which were not peer reviewed or published in the normal way and more often gave weaker or negative results, perhaps because the doctoral student did not have the resources to mount a thorough study. When we read the full papers at the next stage, we can also investigate the correlation between study sample size and mean Effect Size (ES) where available to see whether small studies were more likely to produce small ESs, i.e. that publication bias was not militating against small studies. We can also employ measures such as Orwin's (1983) failsafe N to investigate how many missing studies would be needed to bring the ESs to the p=0.05 level.

There is also a question of interpretation of results here. For Online and Blended Learning which are intended as substitutes for traditional classroom instruction, a "Same" outcome is positive (although not as positive as a "Better" outcome). However, this is not true of Games, CAI or CSCL, which are usually and addition to the normal classroom curriculum. In these cases, "Same" would mean the outcome was just the same as normal classroom instruction but the teacher would have incurred expense in purchasing the technology and time in learning how to use and manage it (although this would also be true of any other digital innovation).

Interpretation and Relation to Previous Literature

One might assume that online and blended learning would have adverse social effects, since separating children from their friends as well as opportunities for direct cognitive interaction with the teacher and other students seems intuitively likely to be damaging. However, this was not posed as a research question in many studies and consequently we found ourselves unable to comment.

Worryingly, some studies of virtual schools in the USA (schools teaching only online which children can opt to "attend" rather than traditional schools) reported that achievement in such schools was below that in traditional schools (Miron, et al., 2016; Ahn et al., 2017; Miron, et al., 2018; Poelmans, et al., 2018; Mislevy, et al., 2020). This could be related to the fact that disadvantaged Caucasian students were over-represented in such schools.

While we have found that online and blended learning are effective, and often more effective than traditional instruction, both of them beg the question of degree of parental or other carer supervision at home. In countries where nuclear extended families are not common, and especially in a situation where both parents need to work and therefore be absent from the house, the child-minding function of school becomes much more significant. Obviously with young children there are also legal issues to consider, but even with older children the question of how on-task they would remain when in the house on their own is another issue. When the online or blended work done at home is assessed quite quickly, the school can see which students are failing to keep on task (or procrastinating), and can perhaps require that they attend school in order to complete their online or blended tasks in an environment where there is a degree of supervision. This might be particularly relevant for disadvantaged pupils who might also have difficult accessing computers and the internet at home. Once the student is performing more satisfactorily, they might be allowed to resume studies at home. Thus, the student can see that working at home is a privilege that can be withdrawn if performance does not keep up to standard.

Ideally, online and blended learning should be available on a variety of devices to improve access, including smart phones and games consoles as well as desktop/laptop computers and tablets requiring an internet connection. One of the advantages of games is that they often do not require an internet connection. However, multiple device platforms should be considered when constructing online learning, as for example a spreadsheet task presents particular issues when viewed on a smartphone.

While we had anticipated a high number of studies in CAI, as many studies of web-based learning within schools had been so coded, we were surprised by the very large number of studies on Games. This is clearly an area of great productivity. However, schools might be using Games in class, but using them out of class is another step which is perhaps less common.

Regarding Games, we anticipate that teachers might wish to ask us to give examples of or recommend suitable serious games for education. One Game did stand out as being widely used and also subject to several positive evaluations - Quest Atlantis (https://en.wikipedia.org/wiki/Quest_Atlantis - also see Amazon and YouTube). However, this Game is quite complicated and requires teacher time to get used to seeing how the game works. This highlights a tension – simple Games might be discarded by teachers as being insufficiently educational, while complex Games might be discarded if teachers cannot find the time to learn them. However, this analysis is perhaps too naïve – if teachers can recognise the inherent educational value in either serious or commercial games of any complexity, they should be motivated to innovate. They also need to recognise that often children are more expert in digital technology than teachers.

Regarding the sub-group analysis, this nevertheless shows that digital technology is widely applicable, not just to ordinary children, but also to those with socio-economic disadvantage, low ability, disabilities, ethnic minority status, in rural schools, hospitalised or sick, and gifted. For teachers, the message is that digital technology is not just for the average or above-average student in a normal educational situation.

Further, 357 studies (23%) were evidenced by the title or abstract as taking place outside the native English-speaking world, in 59 separate countries. The authors of these papers are to be congratulated on successfully writing a paper in their second or subsequent language, but the numbers also indicate that digital technology is widely used outside the native English-speaking world, including in situations which seem deeply unpromising.

Even though this paper is merely a scoping review, we believe it is wider and more thorough and has uncovered some issues not evident from the previous literature.

Implications for Future Practice, Policy and Research

Practice: This paper has been written primarily for teachers (many of whom will doubtless be content with the Executive Summary, perhaps accompanied by dipping into other sections as they feel the need). The return to school risks losing the innovations in online and blended learning deployed by schools during the pandemic. Even though marshalled at high speed

without the benefit of much planning time, these innovations do indicate a new way of working for schools. While wholly online learning is probably not relevant for most pupils except those in remote areas, blended learning certainly offers promise. A system of accessing learning at home or in the public library during the morning with activities and discussion relating to that learning at school in the afternoon is certainly one schools might wish to experiment with. Dealing with disadvantaged or procrastinating pupils has been discussed under Interpretation above.

Policy: Local and national government needs to develop local and national policies for online and blended learning from schools. At present governmental thinking is not sufficiently informed by the evidence base. It may be that teacher unions will be concerned by the suggested shift in teacher practice, but there is no suggestion that fewer teachers will be needed; if anything, more (but better trained) teachers will be needed.

Research: We will now proceed to complete a systematic analysis of these 1540 studies based on reading the full paper. This may result in some additions or changes to the coding, so we propose to undertake a second coding, together with a second inter-rater reliability assessment. Obviously, this will take some time.

Conclusions

1. Do online and blended learning from schools have positive/negative/similar effects compared to traditional classroom teaching or digital learning in school? The answer is Positive for both online and blended learning.
2. Do educational games and computer-supported collaborative learning have positive/negative/similar effects compared to traditional classroom teaching or digital learning in school? The answer is Positive for both, although the evidence for Games is more persuasive than the evidence for CSCL.
3. Are the effects different between primary/elementary schools, middle schools and secondary/high schools? There are similar Positive effects in primary and secondary schools, although with less focus on reading in secondary. Science and Maths are the most popular subjects, but many other subjects are learned in this way. There is less research on middle schools. In addition, web-based learning which was carried out in schools was categorised under Computer Assisted Instruction (CAI), which was also found to be effective, and clearly has the potential to be used outside of school.
4. Are the effects different in different subjects? A wide range of subjects shows positive results, not only Reading, Maths and Science/STEM, but also English, Writing, English as Foreign Language, Critical Thinking, Humanities, Art and Music, and Health.
5. Are the effects different by gender? They are, and girls generally do better than boys. So, the idea that boys are more competent at information technology is an urban myth.
6. Are the effects different for different sub-groups of students? Positive effects are more marked for students of low ability. Disadvantaged and rural students show positive results where access to digital technology is arranged. A wide range of students with special educational needs or disabilities and those from ethnic minorities show positive results. Students in Non-English-Speaking Educational Contexts show positive results

even though the 59 countries they live in are likely to have cultural issues particular to digital learning.

7. Are the effects on socio-emotional functioning and psychological wellbeing positive/negative/similar compared to being in school full-time? The effects on Socio-Emotional Functioning are largely positive although many studies focused only on self-efficacy. Psychological Wellbeing had too few studies to generate any conclusion.
8. What is the evidence for design principles or underlying digital pedagogies in any of these studies? There is a great deal of evidence on these areas which is summarised and given in more detail in the Appendix.
9. What teaching points for effective online/blended learning can be drawn from evidence-based studies? This research question will be answered after we have read the full papers.

Appendix – Design and Pedagogy Pointers from the Research Literature

Online Learning

- Disasters lead to more online learning (e.g. hurricanes in the US) (c.f. covid-19)
- The 2003 SARS outbreak in China led to the government encouraging online learning
- Inter-school tutoring/mentoring in disasters – safe high to unsafe elementary school
- Lack of social information/connectedness (esp. non-verbal behaviour) is a problem
- If no computer at home, kids can come to school to use
- Lack of social presence and cultural inclusion lowers effectiveness
- In US, completely virtual schools operated in 26 states in 2013
- Four states had online graduation requirements in 2013
- Online learning can be presentational or interactive
- Interactive = bulletin board, chat room, collaborative writing - balance needed
- Embed metacognitive guidance/prompts
- Match newer students with more experienced students (classes not relevant online)
- Allow a proportion of working alone if requested by students
- Synchronous is better than asynchronous, or…
- Asynchronous is better than synchronous …
- (Probably both good but not for same purpose)
- Self-regulation and motivation are very important
- A teachable agent not found to raise effectiveness
- Navigability, ease of use and interactivity are important
- Differentiated learning options should be available for a degree of student choice
- Volunteer tutors can include undergraduates
- Volunteer tutors can include preservice teachers – cybermentoring
- Using videoconferencing software raises effectiveness
- Videoconferencing enables tutor to see level of concentration of students
- Small groups of students can meet online with an experienced tutor
- Virtual reality can be incorporated – with virtual manipulatives and peer interaction
- A personalised recording system is effective in raising performance
- A self-assessment tool raises effectiveness
- Procrastination can be a big problem – a failure in self-regulation
- Procrastination – cognitive behaviour therapy best of 4 interventions
- Drop-out can be a problem – have algorithm to predict
- Attention monitoring and Alarm Mechanism is effective
- Inattention and fatigue measuring system can alert student if concentration wanders
- Wording in math problems – little evidence different types effective
- Problem-example vs. example-problem makes no difference
- An annotation-based system creates effective sharing
- Online learning can deliver safety and security education
- Online learning very useful for school refusers (because of bullying and other reasons)
- Online Tournaments can create a sense of challenge (but different levels needed)
- Small rural schools can act as base for online students to give a sense of connection
- Do not apply principles relevant to adults to children
- “Big data” can synthesize outcomes leading to better conclusions
- Longitudinal/follow-up research very much needed.

Computer Supported Collaborative Learning (CSCL)

- Communication and collaboration skills need to be taught
- Off-task behaviour is common even in pairs – it needs scaffolding
- Social challenges can and do occur in CSCL
- Social Network Analysis can identify introverts who need more careful managing
- GAGFS software uses social network analysis to suggest matching
- Group formation – homogenous or heterogeneous better than random or self-selected
- Group size – 3 struggle to reach consensus, 5 encourages social loafing, 4 probably best
- Adding scaffolds in collaborative environments raises performance, but…
- Attempts to scaffold collaboration can lead to worse collaboration – take care
- Collaboration scripts can scaffold CSCL very effectively
- There are also tools to scaffold involving contributor ratings and feedback
- Graphical tools for scaffolding argumentation work better than text
- Assignation of roles does not work so well
- Moderation by an expert improves quality of discussion, but…
- A 2-step flow of communication through opinion leaders may be better than teachers
- Distributed leadership and mutual engagement are very important
- Help-seeking in peer learning is important
- Peer feedback is very important
- There is a Peer Education Diagnostic Learning Environment (PEDALE)
- Self-regulation important but there are different kinds
- Some kinds of self-regulation more important at certain times
- Individuals also need to develop awareness of the learning processes of others, leading to…
- Groups need to develop social shared regulation (not just self-regulation)
- There are tools which enable visualization of individual contributions to group process
- Cultural background can be extremely important – need to be aware
- Synchronous and asynchronous equally effective but different advantages/disadvantages
- Reciprocal synchronous peer tutoring is effective
- The development of argumentation is important but must be based on evidence
- Scaffolding should be provided for argumentation
- Teacher guidance for argumentation (epistemic and interactive) improves performance
- Assessing argumentation quality – tricky but effective
- Effects of argumentation on domain knowledge very small
- Cooperative learning better for writing development
- Video conferencing very effective with shared online workspaces, but…
- Structured interaction better than just discussing video
- Concept maps can be useful in CSCL in pairs
- Wikis are useful for CSCL
- In Wikis, teacher intervention should be dialogic, not directive
- Digital storytelling can be very effective
- Collaborative drawing can use shared canvases and scripted discourse
- Animated graphics more effective than static graphics
- Robots for dialogic discussion can be incorporated in CSCL…
- Including a robot helper for preschoolers to learn words
- Multi-touch tabletops more effective than individual computers for CSCL
- Larger effects noted in science and engineering courses

- CSCL in reading more effective that face-to-face
- With CSCL in class, physical layout is a problem
- Social and Emotional Learning can be supported at home via CSCL
- More interactivity between teachers from different countries needed
- Facebook and Twitter used by students to obtain “information” – “facts” need checking.

Blended Learning

- Template available for organization of a flipped class
- Lo et al. (2017) reviews design principles
- Alonso et al. (2005) has a psycho-pedagogical instructional model
- Blended learning has many different forms
- Firewalls and security restrictions in schools may hamper online learning
- There will be a significant start-up effort
- FCTS software measures readiness of teacher/students for blended learning
- Training improves outcomes
- Digital work before class leading to discussion in class works best
- Incorporate questions to promote student discussion
- Interaction is fundamental – but varies greatly in quality
- Require reflection on student understanding
- Engineered flipped works better than just video + discussion (3 studies)
- Mobile learning on field trips – enquiry into environment outside is effective
- Mobile learning on field trips - need worksheets to scaffold
- Mobile learning on field trips – need guides, scaffolds, supplementary materials
- Mobile learning outside – have butterfly watching app
- Mobile learning for EFL – listening, speaking practice effective – also at home
- Mobile learning for EFL – can take mobile home
- Mobile learning for EFL – more fun, maintains interest
- Mobile learning – rural students benefit more
- Mobile Learning – delivers extra information, enables student sharing, more effective
- Mobile learning – need adapt to individual and gender
- Pre-learning prior to flipping increases effectiveness
- Digital learning leads to more active learners and less passivity
- Concept mapping useful in mobile learning
- Scaffolded problem-posing can lead to improved achievement and self-efficacy
- Meta-cognitive scaffolding for web search is effective
- Blended better than traditional methods for low ability math students
- Simulation in science both visual and interactive heightens learning outcomes
- Interactive video lectures at home are effective, but…
- Video activities are better than video alone
- Virtual peer models can demonstrate effectiveness at questioning in reading
- Dialogue with teacher and peers – students can be facilitators
- Need improve argumentative reasoning – more effective
- Need improve diagrammatic argumentation – more effective
- E-books successful in maths, esp. for low ability
- Station rotation model – mixed results in effectiveness
- Virtual laboratories in science can be effective
- Very high cognitive load will reduce effectiveness
- Low achieving pupils gain most
- Liking not same as effectiveness – some time liking low but effectiveness high
- Self-regulation prompts increase effectiveness
- Self-efficacy leads to increased effectiveness
- Adaptive e-learning responding to the needs of each student is most effective

- Intelligent tutors can be effective but not well linked to curriculum
- 60% of blended learning more effective than 20%
- Anonymous peer assessment more effective
- Online homework more effective than traditional homework
- Online homework more effective than traditional homework esp. for at-risk students
- Children sick at home can get short-term interventions which are effective
- Blended learning for sexual health leads to increased knowledge, but ? behaviour
- First Aid can be taught through blended learning
- Blended learning works for students with learning difficulties
- Twitter can be used and is effective but ? management of it
- A coherent record-keeping system is needed
- Kinaesthetic methods have no evidence to support them
- Can link rural and urban schools – effective for rural schools
- Parents often not on board, not invited or engaged
- Blended learning can work for the most under-privileged in developing countries
- Blended learning enables international collaboration
- Need consistent leadership to heighten teacher confidence
- An iterative phased roll-out of implementation should be planned.

Computer Assisted Instruction (CAI)

- Laptops to Ethiopia led to children improving in reasoning
- Use of technology makes classroom more child-centred, not teacher-centred
- Web-based instruction in classroom more effective than teacher-based instruction, but…
- Comparing Face-to-Face and Internet collaboration, FtF is best
- Teachers with poor skills, little experience and advanced age least likely to participate
- Implementation by teachers has Entry, Adoption, and Adaptation phases – later is better
- Systematic instructional design pays off
- Pedagogically Meaningful Learning Questionnaire explores extent of learner control
- Goal orientation, perceived added value, motivation, flexibility and feedback important
- Increased engagement esp. of multiple modalities important
- Individualised instruction is more effective than standard instruction
- Social interaction outperforms presentation and students more satisfied
- Concept mapping in organising web searches reduces cognitive load
- Concept maps support reading comprehension effectiveness
- Aim for flexibility as well as fluency
- Spread out steps in learning to lower cognitive load and make diagnosis of error easier
- Asynchronous discussion more effective than synchronous
- Can have whole class contributing notes on interactive whiteboard
- Interactive whiteboards useful for small group activity
- Purported “salience” has little effect on achievement
- Automatic personalisation has no effect
- CSCL can be done in class with scripts
- Improving motivation is crucial for effectiveness
- High levels of engagement lead to better performance
- Text-based and image-based feedback show no difference in effectiveness, but…
- Words + graphics are always more effective than just words
- Framework for creative writing increased creativity
- Life-like multimedia materials increase effectiveness
- Dynamic visualisations more effective than static visualisations
- Metacognitive scaffolding very important
- Scaffolds should be visual, spoken and text for higher effectiveness
- Self-regulation very important
- Problem-based learning requires more self-regulation
- Thinking skills relevant to curriculum can be improved
- Discourse can involve questions, explanations and social acknowledgement
- Self-efficacy increases as metacognitive awareness increases
- Procrastination increases as metacognitive ability declines
- Poor general time-use habits lead to procrastination
- Heighten awareness of attention to video lectures by measuring brainwaves
- Matching pedagogical agent to gender of learner yields better effects
- Spatial contiguity enhances effectiveness, esp. in low ability students
- Use cognitive conflict to diagnose misconceptions
- Greater student control heightens effectiveness
- Fuzzy expert system can recommend options for learning
- Digital notepad with prompts had no effect

- Haptic software (haptic joystick) was effective
- 3-D pens were effective
- Podcasts are effective for vocabulary instruction
- Digital story-telling is effective in raising performance
- An Online Transition Curriculum in reading is effective
- Computerised Elaborated Feedback is effective
- E-readers make no significant difference to reading skills
- Paper books more effective than e-readers (? habituation to e-readers)
- Virtual reading coach focusing on basic skills increases fluency
- Focus on Word Automatization led to transfer to more complex word types
- Reading annotation system leads to discussion and raises effectiveness
- E-portfolios improve writing skills and metacognition
- E-portfolios improve writing with peer feedback
- Multi-media simulation leads to higher cognitive load but better learning
- Use Virtual Reality esp. in astronomy
- Caricature animation increases effectiveness
- Schema development strategies improve critical thinking
- Multi-media perception tasks can improve attention
- Matching to Learning Styles makes no difference
- Wearable Technologies may be useful in CAI in classrooms and outside
- Intelligent Tutor systems give metacognitive feedback on errors with lasting effects
- Scaffolding in the design of experiments heightens effectiveness
- Using Question Stems to scaffold response can be effective
- Student question generation improves effectiveness
- Developing productive questioning heightens effectiveness
- Matching groups needs care – consider selection and rotation
- Augmentation of curriculum with mobile devices better than substitution
- Virtual Reality and Augmented Reality not the same – check definitions
- Virtual Reality can be beneficial, but only with prior familiarisation
- Elaborated feedback is more effective than simple feedback
- Manage help-seeking behaviour in relation to challenge – too much is not effective
- Scaffold students to develop assessment criteria for Art & Design – effective
- Mobile tool for problem-based estimation in classroom heightens metacognition
- Link to existing games, e.g. Monopoly – incorrect answer leads to remedial instruction
- Dynamic Assessment possible (with GPAM-WATA) possible and effective
- Dynamic Assessment by computer as good as that by teacher
- Learning Assessment Tool gives feedback and reinforcement
- Interactive Assessment (e.g. drag & drop) – different methods for different purposes?
- Females might have different game preferences to males (teachers and students)
- Caring for a virtual pet increases empathy, esp. for females
- Anti-bullying software exists but no evidence
- CAI for children with learning disabilities is effective and heightens social inclusion
- SEN students show higher gains
- There is CAI for children with Attention Deficit and Hyperactivity Disorder, but no evidence
- Have rural and urban schools linked – My Buddy School scheme
- Need to bridge school-society gap
- External support needed to increase teacher confidence

- Need teacher continuing professional development which is effective – could be online
- Data-Driven Learning is effective – but what is it?
- More parental support needed, not less – a problem in some homes

Games

- Games show big effects for cognition, but almost as big for affect
- Games do not have much effect on behaviour, however
- Games can be used outdoors as well as indoors
- Games need connecting to the school curriculum (2 studies)
- Games offer experience-based learning
- Boredom and confusion are signs games not working (true of other instruction)
- Games improve attention skills - but does this generalise?
- Cognitive, motivational, affective and sociocultural issues all need addressing
- Games can be played individually or collectively, but…
- Peers outperform individuals, whether competitively or collaboratively (2 studies)
- Both collaborative and competitive games lead to improved performance, but…
- Collaborative games more effective than competitive games
- Simulation in games very effective, esp. with active engagement
- Even very disadvantaged children with no previous experience can use games
- Very different cultural contexts mean some games don't fit
- Teacher experience and style makes a difference (2 studies)
- A Taxonomy of Games has been developed (de Lope et al., 2017)
- Guide for Teachers on Selecting Games (Southgate et al., 2017)
- Ease of use is important in effectiveness
- Challenge is important in effectiveness (in relation to ZPD) (2 studies)
- Degree of student control is important to effectiveness (5 studies)
- Interactivity is important in effectiveness
- Peer interactions need to be goal-oriented and purposeful
- Goal-orientation is important in effectiveness
- Goal-setting lowers cognitive load and yields more fun
- Engagement is important in effectiveness
- Scaffolding is important in effectiveness
- Scaffolding reduces "stuckness"
- Metacognition is important in effectiveness
- Feedback is important in effectiveness
- Intrinsic motivation more powerful than game rewards
- Self-explanation can be effective if children respond to prompts
- Self-efficacy very important at start (2 studies), then importance declines
- Games with a Teachable Agent (avatar) no more effective than those without, but…
- Games with a Teachable Agent more effective than those without (3 studies)
- Concept Maps effective in raising performance
- Role playing not effective
- Concept Maps can be used effectively in EFL – grammar concept mapping (2 studies), but…
- Not found effective elsewhere, whether student's or teacher's
- Give background information rather than short-term advice for long-term effects
- Learning Styles (sequential or global) - fitting game to LS increases effectiveness, but…
- Matching game to Learning Styles made no difference (2 studies)
- Field-Independent students achieve better than Field-Dependent students
- Low ability students make bigger gains
- Game before instruction better than instruction before game

- More experience in game leads to more socialisation
- Context needs to be set before game in social studies - active students learn more
- Thinking Aloud and Modelling more effective than writing
- 3-D games are more effective than 2-D games (2 studies)
- Popularity of a game is not necessarily equal to its effectiveness, and…
- Highly motivating games do not necessarily teach anything useful
- Augmented Reality (AR) can increase enjoyment and curiosity, improve socialisation
- Collaborative versions of AR work best
- AR can help link game to real world
- Some learning anxiety need with AR
- More student control with AR better
- Virtual Reality can lead to higher motivation
- Non-competition group did better than competition group
- Anonymous vs. non-anonymous competition both same and both effective
- With competitive games, need same-ability matching, or less able students do worse
- "Racing" game for argumentation increased speed but not quality
- Badges and leader-board ranking improved effectiveness (but desirable?)
- Computer maths drill game had no effect
- Drill and practice in Writing game had weak effect
- A grid-based "MindTool" available to structure sharing
- Games in groups of 12 as effective as in pairs
- EFL vocabulary learners – Watchers gained as much as Players
- Games played in presence of an audience more effective than otherwise
- Background music increases effectiveness (even though it appears distracting)
- "Maths Snacks" are example of very short game, can do several in one session
- Different narrative elements are likely to be relevant to different genders, ages
- Beware of games that are repetitive with no innovation
- There are games for Mental Health (anxiety, depression)
- Games can cultivate student well-being in a dynamic, enjoyable and playful way
- There are games for Autism (but need to program for generalisation) (4 studies)
- There are games for children with Learning Difficulties (2 studies)
- There are games for children with ADHD (2 studies)
- There are games to learn Sign Language
- There are Motion-Sensing games for disabled children
- There is a Privacy Literacy game which is effective
- There are games in Relationships and Sex Education
- Social games are helpful for hospitalised children, esp. those in isolation
- The commercial game Minecraft can be useful
- Difficult to extricate what transferable skills are learned from games
- There are scoring systems in games that track and display progress
- Overall evaluation is difficult as games very different
- Game and learning analytics could lead to the development of algorithms
- Experience with games and e.g. Facebook leads to higher computer knowledge, or…
- Is it just higher confidence?
- Playing more games at home associated with worse outcomes – but what games?
- More exposure to violent games can lead to aggression (2 studies)
- Competitive game play may lead to aggression

- But prosocial games improve prosocial behaviour (2 studies)
- Parental acceptance of games - 60% in favour
- Game designers may be predominantly male – biasing effect?
- Females like instructive games; males like entertaining, competitive games
- Have girls design games – heightens effectiveness (5 studies)
- Girl game designers might encourage STEM careers (2 studies)
- Making games can be outside of school
- Designing games can be more enjoyable than playing them (2 studies)
- Involve end-users in design
- Involve people with disability in design
- There are few policies on the incorporation of games in schools

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